Tax incentives or subsidies for R&D?

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TAX INCENTIVES OR SUBSIDIES FOR R&D?*

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Abstract

This paper studies whether firms' use of R&D subsidies and R&D tax incentives are correlated to two sources of underinvestment in R&D, financing constraints and appropriability. We find that financially constrained SMEs are less likely to use R&D tax credits and more likely to obtain subsidies. SMEs using legal methods to protect their intellectual property are more likely to use tax incentives. Results are ambiguous for large firms. For both having previous experience in R&D increases the likelihood of using tax incentives, while it reduces the likelihood of using exclusively subsidies, suggesting that the latter induce entry into R&D. Results imply that direct funding and tax credits do not have the same ability to address each source of R&D underinvestment, and that on average subsidies may be better suited than tax credits at least for SMEs. From a policy perspective these tools may be complements rather than substitutes.

Keywords: R&D, tax incentives, subsidies, policy mix

JEL classification: H25, L60, 038, O31

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1. Introduction

Tax incentives and direct funding are two policy instruments used in many countries to stimulate private R&D activity. Both belong to a portfolio of tools that includes intellectual property rights (IPRs), public funding of basic research and public provision of venture capital. While IPRs and direct public funding of private R&D have a long tradition, tax incentives have spread gradually across countries, with some exceptions. Figure 1 shows OECD estimates of the relative weight of each instrument as a share of GDP in 2009 by country. Canada, The Netherlands and Japan rely mostly on tax incentives, while direct funding is still preferred in Sweden, Finland or Germany. Other countries use both instruments simultaneously: France, Denmark, Spain, the United Kingdom and the United States.

[Insert Figure 1]

The main economic rationale for using any of these tools rests mainly on the notion that market failures affect private R&D investment. Appropriability difficulties caused by knowledge spillovers, and external funding constraints derived from asymmetric information may lead to underinvestment by private firms, and ample empirical evidence supports both hypotheses. Which particular form public support should adopt to correct for these sources of market failure is, however, a matter of debate. Does each instrument address in practice both sources of market failures? Are there any conditions where one is to be preferred to the other? Is there an "optimal mix" of both instruments? While there is substantial empirical research estimating the effects that each instrument separately has on private R&D investment and outcomes, to the best of our knowledge the explicit comparative analysis embedded in the questions we raise remains virtually unexplored.[1]

[1] The concern about the adequate policy mix is expressed in OECD's documents about innovation policy (see OECD 2010, chapter 4) and in the testimony by the OECD for the US Senate Committee on Finance, OECD (2011b).

This paper aims at providing evidence with respect to the first question by analysing the use of R&D tax credits and direct funding when both tools are available. We claim that if the two main factors causing market failures in R&D, limited appropriability and financing constraints, affect firms' R&D investment decisions, they are likely to be perceived as hurdles for their potential innovation plans. If the policymakers aim at providing support to firms when they are affected by these hurdles, we should observe a positive correlation between indicators of these barriers as perceived by firms and the probability that a firm will claim an R&D tax credit or have direct support or both.

Existing impact evaluation studies have focused so far on testing whether public support leads to additional private R&D investment. We contribute to this literature in two ways. First, we focus explicitly on the role that sources of market failures play in the programme participation stage. This may provide useful insights for interpreting results that are obtained in these studies. To illustrate this point, assume that from an impact estimation exercise with firm-level data we obtain that supported firms on average barely increase their private R&D investment, or that the share of sales of new products, a standard indicator of innovation outcomes, is not significantly different from a control group of non-supported firms. Should the conclusion be that the policy is not effective? Possibly not if the subsidized firm applied for and obtained support precisely in anticipation of imitation, and does introduce an innovation that is quickly imitated. Second, we compare the use of subsidies and tax incentives by firms that can potentially use both and study whether the correlation between sources of market failures and use of each tool is similar for both.

Tax incentives and direct support (subsidies and loans) have been simultaneously available in Spain at least since the early eighties, although a major legal change increasing tax incentives took place in 1995. We use firm-level data from two non-overlapping waves of the Spanish edition of the Community Innovation Survey (CIS), 2003-2005 and 2006-2008, to study this question. We find that

SMEs that face financial constraints are less likely to use R&D tax credits. Instead, they are more likely to use direct public funding exclusively. Regarding appropriability, SMEs that use legal methods to protect their intellectual property are more likely to use tax incentives or both instruments. For large firms we find a different pattern: financially constrained firms are less likely to use both tools, and more likely to have no support. For both types of firms, human capital and previous R&D experience are important determinants of the use of each tool; in particular, previous R&D experience increases the likelihood of using tax incentives, while firms without R&D experience are more likely to use subsidies, suggesting that the latter are able to induce new R&D investment (an effect on the extensive margin) while tax incentives are not. In the case of SMEs, estimates are robust to changes in the definition of dependent variables and for most subsamples of firms.

Our results suggest that direct funding and tax credits do not have the same ability to address the main sources of private R&D underinvestment, given the design of R&D tax incentives and of subsidy allocation in Spain. These findings are consistent with the hypothesis that there are some key differences between both tools. To be able to claim tax credits firms must be able to finance projects with own or other private external resources first and later have positive taxable income, while subsidies provide up-front financing which is independent of the firm's tax position.[2] Firms that face important appropriability difficulties may prefer subsidies as well, because their R&D effort may not generate much additional income if their innovation is quickly imitated, preventing them to benefit from tax incentives. On the other hand, firms that face small appropriability difficulties but are not financially constrained may find tax incentives more appealing than direct support. Provided that crowding out effects can be ruled out, some combination of both instruments could be preferable from

[2] This obviously depends on the specific design of R&D tax incentives. While in Spain and France firms that invest in R&D can obtain a deduction from their tax liability, which therefore has to be positive at some point (both systems contain carry-forward provisions), in the Netherlands firm's the R&D deduction is applied to wages paid to R&D staff, and is thus independent of the tax position.

a social point of view to relying on only one when both sources of underinvestment in R&D are at play.

The paper is organized as follows: in the next section we briefly review the literature most closely related to our research questions. In section 3 we describe some facts revealed by the data. In section 4 we lay out some hypotheses regarding the use of R&D tax credits and subsidies. In section 5 we describe and discuss the empirical analysis. Results are presented in section 6. Finally section 7 contains concluding remarks.

2. Previous evidence

Many firm level studies have found evidence that productivity responds both to a firm's own investment in R&D as well as to others' R&D, the latter being interpreted as a measure of R&D spillovers across firms (Hall, Mairesse and Mohnen, 2010).[3]There is also evidence that SMEs face an innovation financing gap, while the evidence is mixed for large firms (Hall and Lerner, 2010)). But even if the case for intervention seems to be well established, each policy instrument may have drawbacks. Direct public support through subsidies reduces the private costs of investing in R&D, but places high information requirements for the public agency awarding them and may allow for discretionary behavior. Tax credits and allowances may appear to be a neutral, simple and non-interfering tool, but the specific design is important, as they might be easily claimed for projects that yield high private returns and would have been carried out anyway. Empirical evidence evaluating the impact of both tools becomes therefore very valuable for policy design and improvement.

Over the last two decades, a significant volume of empirical research to assess the impact of either direct support or of R&D tax credits on the level of private R&D

[3] Further evidence on spillovers suggests that those associated to product innovations may be larger than those of process innovations, and larger for SMEs than for large firms (Ornaghi, 2006). Spillovers do not completely deter private investment in R&D, as own R&D may still generate sufficiently high returns if the firm can use some appropriability mechanism to control leakages, and enables the firm to benefit from others' R&D by increasing its absorptive capacity.

investment has been produced. The main concern of most of this research has been testing for full crowding out effects, which if confirmed would imply that public resources are wasted.[4] With only a few exceptions (Haegeland and Moen, 2007, Berubé and Mohnen, 2009 and Marra, 2008), however, the effects of each tool have been independently studied.[5] Ignoring that both mechanisms are simultaneously in place in some countries may lead to overestimated effects if firms use both.

Most work on R&D tax incentives has been based on standard investment models, where tax incentives are a component of the user cost of capital. This modelling provides a framework for testing for crowding out effects, but is not designed to ask which types of firms are more likely to use tax incentives, and whether indicators of appropriability or of financial constraints play a part in it. Some researchers have used an alternative empirical approach, based on matching methods (Corchuelo and Martínez-Ros, 2008, Czarnitzki et al, 2011 and Duguet, 2012). This method allows to control for the non-random nature of programme participation by estimating a participation equation. This step has allowed the authors to include an indicator of financial capacity to explain the likelihood of using R&D tax credits, finding a significant and positive relationship, suggesting that this particular policy instrument may not be able to address well one of the sources of underinvestment in R&D.

Several modelling approaches have been used as well to assess the effects of public subsidies to business R&D. To control for the endogeneity of support, a

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[4] For evidence on tax credits, see Bloom, Griffith and Van Reenen (2002) and Lokshin and Mohnen (2011). On direct grants or loans, see González et al. (2005), Czarnitzki, Ebersberger and Fier (2007) and Arqué and Mohnen (2012).

[5] Haegeland and Moen (2007) find that the additionality of tax credits is higher than the additionality of grants awarded through the Research Council and Innovation Norway, which would be consistent with the latter selecting projects with large externalities but low private return. Berubé and Mohnen (2009), use a sample of Canadian firms that benefited from tax credits, a subset of which received subsidies, and find that those receiving subsidies introduced more new products and made more world-first product innovations. Marra (2008) estimates an R&D investment equation and finds that both instruments increase private investment. The possible link between estimate programme participation and indicators of financing constraints or of spillovers is not investigated in these studies.

programme participation equation is estimated in some cases. Firm size, industry dummies, and other firm characteristics are typically included in the selection equation, but no link to indicators of sources of market failures has been fully and explicitly made.[6] Possibly the work coming the closest to this idea is Gelabert, Fosfuri and Tribó (2009), who investigate whether the impact of direct support on private R&D depends on the degree of appropriability. They estimate a programme participation equation that includes indicators of appropriability as well as of financial constraints. Their appropriability indicator turns out not to be significant; the financial constraints indicator is significant but with a negative sign, contrary to expected. According to these results the outcome of the public agency's subsidy allocation would not seem to be consistent, on average, with addressing market failures.[7]

A recent contribution by Takalo et al. (2011) is the first to provide a theoretical model for the R&D subsidy allocation process (firm's application and agency's granting decisions) and private R&D investment. They use Finnish firm and project level data to estimate a structural model and find that technical challenge turns out to be the most significant and important variable in the agency`s subsidy rate decision. The rating, in turn, is found to be positively correlated with some firm characteristics: in particular, with the volume of sales per employee and with being an exporter. They assume away financing constraints. Since R&D tax incentives are not used in Finland, they cannot offer a comparative analysis of instruments. [8]

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[6] Czarnitzki et al (2007) use an indicator of appropriability, but do not include indicators of funding constraints. Hussinger (2008) uses a credit rating index, and finds that firms with better rating are more likely to obtain direct public funding in Germany.

[7] Their sample consists of firms that invest in R&D at least once between 2000 and 2005. Possibly most are stable R&D performers. In addition, their sample is biased towards large firms: average size is about 450 employees. These are firms are less likely to face tight financing constraints.

[8] They model the subsidy programme as a game of incomplete information between a firm and the public agency, where the agency's objective function includes spillover effects and the firm's profits are a function of the expected subsidy rate, which in turn depends on the firm's beliefs about the agency's valuation of its project. Results are consistent with the agency being selective by choosing high quality projects that generate spillovers. Takalo et al. have access to project level data while we do not, their rating equation estimation provides useful insights for our empirical specification.

To sum up, to the best of our knowledge no study has analysed whether there is an association between the two potential sources of underinvestment in R&D and actual use of direct support and of tax incentives, explicitly comparing both instruments and including in the sample firms that are not stable R&D performers or do not invest in R&D but could potentially do it. We also look at the potential effect on the extensive margin of both policy tools. The different nature of these tools in some potentially relevant dimensions, and the different extent of public involvement associated to each, lead to anticipating heterogeneous effects both across tools and across firms.

3. The Data: some facts.

A sketch of the institutional setting is in order before describing the data. In Spain R&D tax incentives and direct support have been simultaneously available to firms at least since the early eighties, although a major legal change increasing tax incentives took place in 1995; some minor changes have followed since. Tax incentives are provided through deductions from corporate taxable income (100% of current R&D expenditures, and 100% write off of R&D fixed assets except buildings) and from the firm's tax liability (the tax credit). The tax credit offered is a combination of incremental and volume based system. There is a (small) tax credit for innovation (non-R&D) expenditures as well. In 2006 to 2008, the total volume of tax credits was somewhat above 300 million € yearly, according to official records. The number of firms claiming tax credits was 3621 in 2006, falling to 3150 in 2008. Direct support, mostly channelled through a public agency, the CDTI, provides grants and loans for firms' R&D and innovation projects. The volume of support provided by CDTI in 2006 was 800 million € (1090M€ in 2007, and 766M€ in 2008), for about 1000 projects. Direct support is thus at least twice as large as the volume of tax credits, although it reaches a smaller number of firms. [9] In appendix A we provide a more detailed account of both policy tools.

Our empirical analysis is based on data from the PITEC, a firm-level panel data set developed by the Spanish Statistical Office (INE) as a by-product of the European Community Innovation Survey, which in Spain is conducted yearly.[10] It collects information related to innovation activities of firms with more than 10 employees in all manufacturing and service industries. Answering the survey is mandatory in Spain, and the response rate is high (about 90%).

We use data from the surveys conducted from 2005 to 2008, and focus on manufacturing firms. It is important to note that some questions refer to a three year period (2003-2005; 2004-2006; and so on) and others to the survey year. Examples of the first type of information are geographical market of the firm, introduction of new products and/or processes, use of information sources, cooperation to innovate, barriers to innovation, use of public support to innovate and use of intellectual property protection mechanisms.

In 2008 several questions relating to the use of tax credits were introduced in the survey. Firms were asked whether they took into account the potential tax credit they could claim for their R&D investments, whether they had claimed tax credits in 2008 and each of the previous four years.[11] As for direct support, the questionnaire includes every year, since the launching of the survey, two questions on this issue. One asks strictly for the amount of R&D subsidy (non-reimbursable funds) received that year from each different level of the public administration; the second asks whether the firm received any kind of public support (basically loans and subsidies, but the wording is ambiguous with respect

[9] See Dirección General de Tributos and CDTI annual reports.

[10] PITEC is the abreviation for "Panel de Innovación Tecnológica en las Empresas". A description of the survey can be found at the following link (in Spanish): http://www.ine.es/. The Community Innovation Survey has been widely used for innovation and policy evaluation studies; Mairesse and Mohnen (2010) discuss some its characteristics and shortcomings.

[11] The total number of firms that declare using tax incentives in 2008 in PITEC is 1742 (manufacturing and services); our sample covers thus about 55% of all claimants that year.

to tax credits) in the years 2006-2008. We base our description and baseline estimation on the first question.

We measure each type of support across the three year period: a firm is classified as having an R&D subsidy if it declares obtaining one at least one of the three years in the period, and similarly for tax incentives. The sample includes both R&D and non-R&D performers, as the latter are potential support users and we are interested in identifying the features both of firms that have and do not have support. We split the sample in two groups according to firm size.[12] Table 1 describes the use of R&D support by type, where subsidies include only grants. It shows that large firms benefit more from both tools, as only 36% do not have any form of support, while this figure is 47% for SMEs, and that SMEs benefit more, in proportion, from subsidies. The category of firms with no support may include some that perform R&D and did apply for a subsidy but were rejected, or that were unable to claim tax credits because of low taxable income, as well as firms that do not perform R&D.

[Insert Table 1]

A distinctive characteristic of the CIS survey is that it provides qualitative information on barriers to innovation as perceived by the firm, as well as on the importance of several sources of information for the firm's innovation process. This set of questions can generate indicators of potential sources of underinvestment in R&D. In particular, firms are asked to rank a series of potential barriers to innovate. The main barriers of interest are financing constraints, both internal and external, demand uncertainty and the extent to which the market is dominated by established firms.

[12] SMEs that have received any form of public support for R&D or those that have reported R&D expenses in the current or past years are surveyed every year. The remaining firms come from a random sample stratified by size and sector among non-R&D performing firms. Innovators are over represented: over 50% of SMEs in the PITEC sample invest in R&D against 13% in the population, according to INE. In the case of large firms, the figures are 72% and 62% respectively.

Table 2 below shows the percentage of firms that considered each barrier to be of high importance in 2003-2005 by support status, as well as their use of legal intellectual property protection mechanisms. Support status appears to be correlated with financing constraints and use of protection, and, for SMEs, also with lack of personnel.

[Insert Table 2]

Lack of internal and external finance, together with uncertain demand, are the barriers most often perceived as important. SMEs are more sensitive to these barriers than large firms. They are more sensitive as well as to other barriers such as access to information on markets or technology. The simple correlation among the first three barriers is high (about 0.7), while it decreases across the remaining barriers. We have checked whether firms change their perceptions of barriers between the 2005 and 2008 surveys, and find that about half of the firms keep the same perception. Almost all that change their answer do so only moderately (they may change from level of importance "high" to level "medium", but very few change from level "high" to "not relevant").

Quite surprisingly, the survey does not include any direct question related to the firm's concern for imitation by rivals, which would provide an indicator of expected appropriability difficulties. The current version of the Spanish CIS asks firms about the actual use by the firm of legal protection mechanisms. We assume that use of these mechanisms signals that a firm believes that threat of imitation is important and that using legal protection may prevent it at least to some extent.

It is interesting to note that not all firms that were investing in R&D in 2005 (in-house R&D) claimed tax credits in subsequent years: 65% of SMEs and 41% of large firms. Many firms, mostly SMEs, declare that the main reason for not claiming is that their R&D expenditure is too low; some large firms declare that their type of R&D does not fit eligible expenditures.

Other variables may be associated to support status. Firms are heterogeneous in potential innovative capacity; R&D fixed and sunk costs, and expected benefits from R&D. These features may affect their ability to both claim tax credits and to apply and obtain subsidies. Table 3 shows the median level of some proxies for these factors (2005 values) by support status in the period 2006-8. Some patterns emerge: firms that benefit from tax credits, alone or combined with subsidies, have slightly higher human capital than those without support or with only subsidies; there is also a higher proportion of firms with previous R&D experience among firms that claim tax credits than among firms with only subsidies. Relative productivity is also higher for firms that benefit from tax credits, either alone or combined with subsidies.

[Insert Table 3]

This description suggests that there may be a correlation between the type of support used and firms' perception of financing constraints, although mildly so in the case of large firms, as well as an association with the use of protection mechanisms and past R&D experience. In the next section we provide some arguments as to why these patterns may be expected.

4. Direct and indirect R&D support: some differences and hypotheses.

The purpose of this section is to discuss some hypotheses about the potential relationship between the barriers firms face to perform R&D and the use of each instrument. We do not develop a formal model of firm's R&D investment strategy and participation decisions, but conduct an informal discussion that leads to some conjectures about that relationship.[13]

We start by pointing out that some differences in the design and timing of R&D subsidies and tax incentives may determine who is more likely to benefit from

[13] While there is theoretical work comparing patents, prizes and subsidies (Fu et al 2012), to the best of our knowledge tax incentives have not been included in these comparisons.

each. Direct public funding (subsidies and subsidized loans) is obtained only if the firm submits an application to the public agency and this agency decides favourably after screening the proposals. The requirements explicitly and publicly set by subsidy awarding agencies are often related to the innovative content of the proposal, the technical ability of the firm to carry it out, and the potential market.[14] The agency may rate projects along several dimensions, such as potential for generating additional social value, i.e., spillovers, or for generating radical innovations through collaboration with public research labs or with universities. It may as well take into account whether firms face financing constraints, although these items are not always necessarily made public.

Grant awards are thus based on the merit of the projects according to the agency's assessment. If the agency has good quality information and is able to anticipate either the potential for spillovers or the financing constraints faced by the firm, it can tailor the magnitude and duration of direct support to the particular features of the project, although a maximum subsidy rate is often set in practice. The firm runs the project once funding has been approved and usually the agency provides a down payment to start the project.[15] It should be noted that application is not costless, as preparing a good proposal requires at least time and qualified labour. Funded projects reflect both a firm's decision to apply and agency preferences.

R&D tax incentives, on the other hand, do not require the approval of a specific project by a government agency. Provided as tax credits –a reduction from the tax liability- or as tax allowances –a deduction from taxable income-, they are targeted to all potential R&D performers, irrespective of the quality of the project.

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[14] There may be important differences across countries in the specific design of direct support. In the United States, the description of SBIR programme, which targets SMEs (see http://www.sbir.gov) states that R&D risk and fixed costs are key motivations for the programme. Public agencies involved with the programme set R&D topics in solicitations. In Finland, the public agency Tekes values the degree of novelty and research intensity of projects but does not appear to set specific topics (http://www.tekes.fi). The Spanish case is similar to the Finnish. See Huergo and Trenado (2010) for a detailed description of the Spanish case. The European Union Framework Programmes require proposals to have European level added value and usually transnational cooperation.

[15] Once the firm has had a project proposal approved, it may be able to obtain additional funding from the private sector. Agency approval may act as a quality certification.

There may be volume-based credits or incremental credits, or a combination of both; upper limits on the amount of tax credit may be set. A firm may claim a tax credit on any expense that qualifies as a research and development expenditure according to the tax code; the only requirement is for the firm to follow proper accounting rules for this type of expenses. To be able to benefit from a tax credit the firm must have a positive tax liability, unless a refund system is established.[16] The cost of claiming tax credits can be expected in principle to be lower than the cost of applying for subsidies, since a firm must file for taxes every year anyway.

When tax credits are applied to the corporate tax, they may be looked at as an ex-post prize for successful innovation outcomes, while when they are applied to the corporate wage and social contribution tax, they act as a prize for R&D effort (searching for ideas, which may be unsuccessful), regardless of the outcome. This difference may be important for firms' decisions, because in the first case the ability to claim the prize depends on the firm's tax position, but not in the second case. We will focus here exclusively on the possible differences between subsidies and tax credits applied to the corporate tax liability because this matches better the legal environment that firms in our sample face.

From this description, several potentially relevant differences between subsidies and tax credits can be noted in three respects: i) eligibility/requirements; ii) magnitude and certainty of support; iii) timing of support.

Eligibility/requirements: while any R&D project may qualify for a tax credit, a partially different set will qualify for a subsidy. All privately profitable projects qualify for a tax credit. Some of these, but not all, may qualify for a subsidy as well, provided that they satisfy the agency's requirements: quality level, extent of radical (rather than purely incremental) R&D, generation of additional social value, even if they generate sufficient private returns. But subsidies may in

[16] In some countries other than Spain the design of R&D tax incentives may allow firms to get a direct refund of their tax credit if the firm has no tax liability, so this requirement would not apply (see France and UK, for young innovating firms, or Canada, for all firms domestically owned).

addition encourage projects that would not be privately profitable otherwise, therefore unable to generate profits and hence a positive or significant deduction.

Magnitude of support: although both tax incentives and subsidies imply a cost reduction, subsidies provide more certainty on the extent of this reduction for the firm. If awarded, the firm knows the amount of support it will get, whereas in the case of tax incentives the effective support depends on the firm's tax position, which may be difficult to predict especially for SMEs. In addition, subsidies may be tailored to the nature of the difficulties associated to the project, i.e., whether these are spillovers (with grants), or financing constraints (with loans), or both.

Timing of support: subsidies usually provide upfront funding for R&D projects, while tax incentives do so after the project has been privately funded. In the case of tax credits, independently of whether they are applied to the corporate tax or to wage or social security contribution taxes for R&D employees, the firm must be able to fund the project in advance. While large firms are less likely to suffer from financial constraints, new firms and SMEs may be less able to start an R&D project because of lack of both internal and external funding, and therefore unable to benefit from this instrument.[17] In addition, R&D subsidies not only provide up-front funding for R&D, but also may provide a signal of the quality of a project to potential private investors. Tax incentives cannot perform this role. Again, this feature may be of special relevance to new firms and SMEs.

Another important issue in R&D decision-making are fixed and sunk costs, which may become an entry barrier for some firms. Previous empirical work with Spanish firms provides evidence (González et al 2005, Máñez et al. (2009) and Arqué and Mohnen (2012)). Arqué and Mohnen analyse the role of subsidies as a tool to induce R&D investment by previously non-R&D performers (the extensive margin) in addition to the usual intensive margin effect, and find that indeed about 25% of Spanish manufacturing firms need subsidies to start, but not to continue,

[17] Recent evidence suggests that constrained firms are less likely to start innovative projects (Hajivassiliou and Savignac, 2008).

R&D activities. Finally, Aw et al (2011) study the relationship between R&D and exporting in a dynamic setting allowing for sunk costs to both activities, implying that the firm's past exports and R&D should affect current decisions. They find significant evidence consistent with the presence of sunk costs in both. Whether tax incentives can also play this role is an open question which we can investigate.

We claim that when firms' potential R&D projects differ across some or all the features that generate underinvestment: risk of imitation (appropriability), financing constraints and sunk costs, these differences will affect firms' decisions as to which instrument to use, given the differences just described. Our first conjecture is that when a firm's potential R&D projects suffer from significant appropriability difficulties, it will prefer to apply for a subsidy because the agency can set a sufficient subsidy level to compensate the firm for the lower expected private return. When expected spillovers are large the project may generate very little taxable income, so potential tax deductions may be too low to compensate for profit erosion. For low spillover levels, or if the firm is diversified so that it obtains sizable taxable income from other products, then tax credits may be more attractive than subsidies, as the expected subsidy might then be low and below the cost of applying.

Our second conjecture concerns the relationship between financing constraints and type of support. In the corporate taxation literature, Keuschnigg and Ribi (2010) predict that R&D tax credits will not only encourage innovation but also relax financing constraints and help innovative firms to exploit investment opportunities to a larger extent. We believe, however, that in absence of spillovers, SMEs and young firms that are financially constrained are more likely to prefer and obtain subsidies. Subsidies provide upfront funding to start a project, and in addition may enable firms to obtain additional private funding as a result of a certification effect, unlike tax credits (Takalo and Tanayama, 2010).[18] For large

[18] Takalo and Tanayama develop a a theoretical model of the allocation of direct R&D subsidies in a context of financial constraints derived from asymmetric information. There are three types of agents: financially constrained entrepreneurs whose projects may be of low or of high quality,

firms, however, the expected tax credit may be more predictable and large, and may help them mitigate milder financing constraints. Finally, our third conjecture is that the presence of sunk costs would also make subsidies more appealing to potential entrants into R&D.

To sum up, this discussion suggests that tax credits and direct support may not have the same ability to deal with both sources of market failures: when these are significant, subsidies would be better suited to address them, especially for SMEs and young firms. When they are mild, tax credits may do it, especially for large firms. We should therefore observe a positive correlation between financial constraints and use of subsidies, and a negative correlation between financial constraints and use of tax credits. Regarding appropriability, we would observe high appropriability to be positively correlated with the use tax credits, and low appropriability positively correlated with use of subsidies. If indicators of financing constraints and of appropriability difficulties are available, these predicted patterns could be tested.

To test these predictions we will use a two equation discrete model (a bivariate probit model). Indicators of financial constraints, appropriability and past R&D investment will be the key independent variables. We will take into account as well other factors that may affect a firm's support status, which include those that shape the incentives to innovate and perform R&D. These are, among others, competitive pressure, distance to the productivity frontier, and innovative capacity. As in most existing research in this area, we take a reduced form approach as an approximation to a complex decision process, since we do not have information to model the agency's awarding decisions.

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private investors and a public agency. The public agency's role is mainly to identify high quality entrepreneurs, such that by granting a subsidy it provides a signal to private investors in addition to the subsidy itself, enabling the firm to obtain private external funding. The model predicts that firms with high quality entrepreneurs will always apply for funding, while firms with low quality projects will apply with some probability.

5 Empirical Analysis

5.1 Variables

We use two non-overlapping waves of the CIS survey. Our dependent variables are obtained from PITEC 2008, where questions refer either to the period 2006-2008 or to year 2008. In order to be able to deal at least partially with potential endogeneity issues, we use most explanatory variables from PITEC 2005, where questions refer to the period 2003-2005 or to 2005. We describe next the core variables we use; Table 1B in Appendix B provides descriptive statistics.

Dependent variables

We define two binary dependent variables: *Tax Incentives* and *Subsidies*. For *Tax Incentives,* the binary variable equals 1 if the firm declares having claimed tax credits any year within the period 2006-2008. We believe that since tax credits are subject to carry-forward provisions, using a three year period instead of a single year may provide a more accurate description of firm behavior. We later test for the sensitivity of results to changes in the definition of the dependent variables, and use annual observations instead.

Subsidies. We define a binary variable which equals 1 if the firm has obtained direct funding (only subsidies are included in this definition, loans and public contracts are excluded) from the Central Administration any year within the period 2006-2008, which obviously implies that the firm has applied for support. Note that the survey does not provide information about whether a firm applied for but did not obtain direct support. The observed status captures then not only the firm's decision to apply but also the public agency's preferences. The awarded funds may spread over more than one year, as funded projects may run from 1 to 3 or 4 years, so using a three year period may again be appropriate. Although firms may obtain direct support from local, central or European administrations, we consider that since R&D tax incentives are a policy implemented by the

Central government, they should be compared to the direct support policy from the same government level.[19]

Core Independent variables

Financing constraints. Cash flow has been frequently used as a proxy for financing constraints in R&D investment equations. As this measure has been subject to criticism, some researchers have recently turned to using direct measures of financing constraints which are derived from direct questions in surveys (Gorodnichenko and Schnitzer, 2010; Hajivassiliou and Savignac, 2011, Peters and Hottenrott, 2011).[20]

Direct measures of financing constraints may have some advantages relative to cash flow or similar measures, but they may in turn suffer from other shortcomings. Previous studies that use CIS data have obtained counterintuitive results with respect to the correlation between barriers and innovative activities. In a study by the OECD (2009), reporting the results of a multi-country firm-level estimation of a variant of the Crepon-Duguet-Mairesse model of R&D and productivity, the estimates show a positive association between most barriers and the probability of engaging in innovation activities for most countries.[21] A possible explanation that has been offered is that innovative firms become more aware of the difficulties associated to innovating than non-innovative firms. This interpretation suggests that self-assessment of barriers may be endogenous to innovative behavior, particularly because in these studies both sets of variables refer to the same time period. An additional problem is that there may be

[19]Regional or local governments do not provide R &D tax incentives. There is however one particular case, the Basque country, where the cap on the tax credit does not apply. Regarding direct support, eligibility criteria for support may differ both across government levels and across regional agencies (Blanes and Busom, 2004), so aggregation might distort results. Overall, the volume of regional government support is small.

[20] Hajivassiliou and Savignac use a French firm-level data set that includes direct, subjective direct indicators of financing constraints similar to ours as well as objective but indirect indicators such as leverage ratio, cash flow or the profit margin. They find that they are highly correlated. When accounting for the possible simultaneity between contemporaneous financing constraints and the probability of engaging in innovation activities, they find that financing constraints have a negative effect, as expected.

[21] The same type of firm-level data source and methodology were used for each country and the data were fundamentally a cross-section..

individual-specific heterogeneity in subjective evaluations of constraints: some respondents may tend to be optimistic, while others pessimistic. We address these concerns by i) using lagged indicators of barriers, ii) dropping from the sample firms that declare that there is no need to innovate as the main reason for not doing so, and iii) measuring the relative importance of each barrier with respect to the average importance of all barriers for that firm.[22]. We expect this lagged variable to control both for the subjective overall individual-specific perception of difficulties and for endogeneity, to some extent. As described above, firms report the degree of importance of lack of access to internal and to external financing as a barrier to innovation. Because of the observed high correlation between both barriers, we define a single measure for both. In our sensitivity analysis, we will redefine this as binary variable which equals 1 if the firm considers that either barrier is of high importance. [*Financially constrained*]

Appropriability. In most existing empirical work the standard indicator of appropriability has been the use of legal protection mechanisms. We also take this approach and define a binary variable which takes the value of 1 if the firm has used any of them (copyrights, trademarks, design or patent) in the period 2003-2005 [*Appropriability*]. As this variable might capture as well past innovation experience, we will include past in-house R&D. In addition, the inclusion of past R&D serves as an indicator of whether the firm faces R&D entry sunk costs. [*Did-in-house R&D*]

New firm. Young or newly created firms may face specific difficulties to pursue R&D projects, since they are likely to lack internal funds, reputation and credit history. Private external funds will be hard to get in these conditions. In addition the public agency may offer particular support to new technology based firms.

[22] An alternative way we explore to deal with these issues is to include an additional control variable that aims at capturing the firm's overall perception of difficulties. It is computed as follows: we add the rankings given by the firm to each barrier, and rescale so that it takes values in a 0 to 1 range. It captures the firm's "Awareness of constraints": larger values indicate that a firm perceives a high overall level of barriers. We later check for the robustness of estimates to alternative ways to control for these potential biases.

Since the survey records whether the firm is new, we define a binary variable to represent a new firm in 2003-2005. [*New firm*]

Other variables and controls.

The survey provides information relative to other barriers to innovation as perceived by the firm, described in Table 2. We include the following, each calculated as the ratio between the rating given by the firm to that particular barrier and the sum of ratings of all barriers declared by the firm. *Dominant Firm:* The existence of an established dominant firm may have disincentive effects on other firms (Cabral and Polak, 2007). *Demand risk:* Uncertain demand for innovative goods or services may be an important barrier for firms, especially for SMEs or firms that produce a single product. Other barriers included in the empirical specification are *Lack of personnel* and *Lack of information*.

Some firm characteristics affect their ability to generate innovations and to benefit from them.. *Human capital* is an undisputable driver of the ability of a firm to generate ideas and high quality R&D projects and to use external knowledge. Both macro and firm level studies provide evidence in this respect (Leiponen 2005). A firm's human capital has several dimensions, including manager's abilities, human resource management practices, and employee skills. As a crude measure of human capital we use the proportion of employees with a higher education degree, defining several intervals to account for possible non-linearities. These intervals are: no high degree employees, positive but less than the median, between the median and the 90th percentile, and higher [*Low educated, Medium-Low, Medium and High Educated*]. In addition, each firm was asked whether existing tax incentives were taken into account when planning its potential R&D investment. We believe that the answer may capture the managers' standpoint on the strategic importance of R&D for their firm. Lacking other indicators of managerial characteristics that might be relevant for innovation decisions, we include this binary indicator as a control variable [*Take into account tax incentives]*.[23]

Technological Rivalry: The importance that the firm gives to information from competitors as a source of ideas for innovation is usually interpreted as an indicator of incoming spillovers (Cassiman and Veugelers, 2002). We believe it may also capture at the same time the extent of technological and product market rivalry in the firm's industry as perceived by the firm. We would expect firms in this kind of neck-and-neck competition to be more likely to apply for and use all types of public support. [24]

Incentives to innovate may be affected by the firm's position relative to the technological frontier (Aghion et al., 2009). In addition, returns to innovation may be higher for more productive firms (Aw, Roberts and Xu, 2011). We will consequently include a measure of productivity distance of the firm relative to the mean of its sector of activity. Manufacturing is classified into 30 subsectors, and for each we compute the average labour productivity as sales per employee. We then divide each firm's labour productivity in 2005 by the average of its subsector [log *of Relative productivity*]

Finally, the following binary variables are added to control for other sources of heterogeneity: belonging to a group [*Group membership*], being a private domestic firm [*Private domestic firm*], being an exporter [*Exporter*], whether or not the firm invested in physical capital in 2005 as a proxy for demand expectations [*Fixed investment*], location near a science or technological park [*Located in technological park*], regional location and industry dummies capturing technological intensity [*high, medium high, medium low and low*]. Firm

[23] Note that taking into account tax credit incentives does not predetermine claiming them. Although most firms that do not take them into account do not claim tax credits, 56% of SMEs and 60% of large firms that do take them into account do not claim them. The Pearson correlation between the two variables is .28 for SMEs and .30 for large firms.

[24] This information is not available for all firms in the sample, but only for innovators.

size is accounted for by a set of binary variables for each of a series of size intervals, according to the number of employees.

5.2 Econometric Model

Our two dependent variables, use of tax incentives and use of subsidies, are binary. We specify and estimate a bivariate probit for several reasons: i) it allows for correlation between the random terms across alternatives, and ii) it possibly captures more accurately outcomes of the decision processes of the firm and the agencies: tax filing periods may not be the same as grant application and granting periods; in addition, firms may not be able to anticipate their tax position when applying for direct funding. A Multinomial logit model with four alternatives would not be appropriate, as the IIA assumption is likely to be violated.

We drop from the sample those firms that declare not having an interest in innovating, as we want to focus on the role of barriers for firms that do have a potential interest for innovating, thus distinguishing between behavior resulting from preferences from behavior resulting from perceived restrictions. We keep in the sample firms that do not do R&D because these are potentially innovative firms that may have applied for support but not obtained it, or find that expected support is too low, given the innovation barriers they face.

We would expect to find the following patterns in the data: i) a negative correlation between financing constraints and the likelihood of claiming tax credits, particularly for SMEs and young firms; ii) a positive correlation between financing constraints and the likelihood of applying for and obtaining direct support; iii) a positive correlation between appropriability difficulties and direct support; iv) the correlation between appropriability difficulties and use of tax credits may depend on the magnitude of spillovers (possibly positive for small spillovers), and v) a positive correlation between previous R&D experience and use of tax incentives.

These patterns should be most clearly distinguishable in the cases where firms *use only tax credits* and where they *use only grants*. Some firms will use both tools at the same time (see Table 1 above): these firms may have more than one R&D project, one being subsidized because of spillovers while the others generate taxable income; or may have obtained a subsidy because they face financing constraints but not appropriability difficulties. We do not have information at the project level to disentangle this. On the other hand, we expect *not using any support* to be related mostly to low innovative capacity: firms that have a low level of human capital, or perform basically imitative innovations. However, firms that are moderately innovative (their R&D is mostly of an incremental nature and thus does not qualify for a subsidy) may also be in this category if they have little taxable income.

The model consists of a direct support equation (S), which can be viewed as a reduced form of the application and granting process, and a tax incentive equation (T): [25]

(1) $$S = 1 \text{ if } S^* = b_s X + e_s > c, \quad S = 0 \text{ otherwise}$$

(2) $$T = 1 \text{ if } T^* = b_t X + e_t > h, \quad T = 0 \text{ otherwise}$$

where e_s and e_t are jointly distributed as a bivariate normal BN($\mathbf{0}$, $\mathbf{1}$, ρ), S and T are the observed binary variables for use of direct support and tax credits in the period 2006-2008, and X are predetermined explanatory variables.

There are be four possible situations a firm can be in: no support (0,0); uses only tax credits (0,1); uses only a direct subsidy (1,0) and gets both a grant and claims a tax credit (1,1), and therefore four sets of corresponding joint probabilities. Several types of marginal effects may be computed; we report below the average

[25] Note that we do not have information on R&D direct support application: firms are not asked whether they applied for but did not obtain public grants or loans.

marginal effect, which is the average of the marginal effects evaluated at each value of x.

6 Results

6.1 Baseline estimation

We perform separate estimations for SMEs and for large firms. Table 4 (SMEs) and Table 5 (Large firms) report the estimated average marginal effect of a change in explanatory variables on the joint probability of each of the four possible situations a firm may be in. We perform several tests. We test for equality of coefficients across equations (1) and (2), for the four core variables: financing constraints, appropriability, past R&D and new firm. The null is rejected for the first three variables in the case of SMEs, and rejected for the last two in the case of large firms.[26] As a specification test, we perform a test for normality of residuals, and do not reject the null for both samples. We also test for endogeneity of financing constraints, using the Blundell-Smith test; we do not reject the null. [27] Finally, we obtain a low but positive and significant correlation between the residuals of both equations, suggesting that some unobserved variables affect the use of both instruments in the same direction (rho=0.08 for SMEs and rho=0.12 for large firms).

Next we discuss the estimated average marginal effects we have obtained for the probability of using only tax credits and of using only direct support, as we expect the results of these two cases to offer a sharper picture of the differences between both tools. For SMEs, we find that being *financially constrained* reduces the probability of using only tax credits by about 4 percentage points, while it increases the probability of obtaining direct support also by about 4 percentage points. These results are consistent with the expected patterns. Regarding *appropriability*, as captured by the use of legal protection mechanisms, we find

[26] Chi-square tests not reported in the tables but available on request.

[27] For the normality test, see Chiburis (2010). We perform the endogeneity test separately for subsidies and for tax incentives. Firm's age is used as instrument for financing barriers.

that SMEs that have protected IP in the preceding period are more likely to use tax incentives, either as a single tool or in combination with subsidies. Since we control for past R&D investment, we believe that this result suggests that firms that protect their innovations are more likely to generate profits and are therefore in a better position to claim tax credits.[28] Access to grants, instead, is independent of appropriability status. With respect to previous in-house R&D experience, we find again opposite patterns across firms that use only one or the other tool: previous experience is positively correlated with using tax incentives only, and negatively correlated with using grants only. This suggests that subsidies can induce firms to invest in R&D, while tax incentives alone are quite less likely to do so. We can infer that the agency awarding direct support cares about increasing the number of R&D performers, rather than only focusing on increasing the R&D intensity of stable performers. This result is in line with Arqué and Mohnen (2012). Tax incentives instead are more likely to benefit stable R&D performers. The subsidy policy and the tax incentive policy may be complementary in that respect. A formal test of complementarity as in Mohnen and Roller (2005) is however beyond the scope of this paper.

We find other interesting differences in the impact of other variables on these probabilities. A high level of human capital increases the likelihood of using only direct support, suggesting that firms with high quality projects are more likely to use grants. A firm's relative productivity is positively correlated to the probability of using tax incentives only, but negatively with the probability of receiving subsidies. Firms in the smallest size intervals (less than 20 employees and between 20 and 50) are less likely to use tax incentives, while they do not show any disadvantage relative to larger firms in the use of subsidies. Finally, we find different patterns across industries. Firms in high-tech and medium-high technological intensity are more likely to use tax incentives only. It is remarkable

[28] Although applying for direct support entails revealing project information to the public agency, the agency does not disclose this information to the general public. If the firm obtains direct support its R&D costs fall even if imitation by rivals is immediate, whereas it might be unable to use tax credits if innovation barely generates profits.

that none of the other innovation barriers appears to be on average correlated with the use of public support.

We now look at the other two groups of firms: those that do not use any support, and those that use both tax credits and direct support. We find that having previous experience in R&D is one of the most important determinants of using both kinds of support, jointly with managerial awareness of R&D incentives. Having a high proportion of highly educated employees increases the likelihood of using both types of support; since this variable is not correlated with using only tax incentives, this result corroborates that at least for SMEs the public agency succeeds in selecting high quality R&D projects. The likelihood of not using any support is higher for firms without human capital, without previous R&D experience, low productivity and for non-exporters. These results are in line with Aw et al. (2011) and Takalo et al (2012). Smaller firms are also more likely to be in that group.

Results differ somewhat for large firms. We do not find a significant correlation between financing constraints or appropriability and the likelihood of using tax incentives only or subsidies only. Financing constraints are inversely related to the probability of using simultaneously both instruments, and directly related to using none. We also find that the most distinctive difference between firms that use only tax incentives and firms that use only subsidies are the role of human capital and previous R&D experience. Firms that do not have human capital are less likely to use tax incentives (the probability falls by 0.14 pp), while they are more likely to obtain subsidies (the probability increases by 0.11 pp). Subsidies appear in this case to be used to increase the innovative capabilities of some firms, a role that tax incentives do not perform. An finally, firms that have previous R&D experience are more likely to use tax incentives only or both forms of support, while firms without previous R&D experience are more likely to obtain direct subsidies, in line with the result obtained for SMEs.

Overall, our results suggest that direct support may be more effective to encourage firms that face financial constraints to invest, or invest more, in R&D, while tax incentives may encourage increasing R&D by firms that are not financially constrained and already invest in R&D. Direct support and tax incentives would therefore not be substitutes, as the latter would not be well suited to financially constrained firms. Tax incentives may provide some compensation to firms affected by low appropriability difficulties, particularly for SMEs. For large firms the indicators of market failures appear to be unrelated to the use of both policy tools. Instead, previous R&D experience and the firm's level of human capital do seem to play a role in the use of each instrument, with grants being able to induce non-R&D performers to invest in R&D, and to increase the innovation capability of firms with very low levels of human capital.

[Insert Table 4]

[Insert Table 5]

We also estimate the model including as a proxy for technological rivalry the importance to the firm of information from competitors.[29] Because only firms that were innovators in 2005 answer this question, the samples are somewhat smaller (about 300 SMEs less and 100 large firms less than in the estimation above). We find that SMEs that consider that information from competitors is highly important are more likely to use subsidies only, and less likely to use tax incentives only. For large firms, the likelihood of using both increases when competitors' information is important, while the likelihood of not using any falls. These results are consistent with neck-and-neck competition. As technological rivalry pushes SMEs to use subsidies only rather than tax incentives only, we may infer that what leads these firms to apply for and obtain direct support is that their R&D projects are likely to benefit rivals through imitation.

[29] Results not reported but are available on request.

6.2 Robustness analysis.

In this section we explore the robustness of our results to (a) differences in the firms' innovativeness status, (b) changes in the definition of barriers to innovation, and (c) alternative definitions of the dependent variables.

We begin by re-estimating the baseline model for different subsamples of firms. We first estimate the model for the subset of firms that introduced products new to the market in 2005 or before, because this particular subset may be more sensitive to appropriability issues; second, we re-estimate for the subset of firms that were doing R&D in 2005, and finally we estimate the model for the subset of firms in high tech and medium tech manufacturing sectors.

Second, we change the way we calculate financing and other constraints. Instead of computing the relative importance of each particular constraint for the firm, we generate a binary variable for each barrier which equals 1 when the barrier is of high importance to the firm, and include an index of the level of overall barriers.

Third, we change the definition of dependent variables, a firm's use of tax credits and of direct support. Instead of using variables referring to the 2006-8 period, we use binary dependent variables referring to year 2008 only. We also reestimate the model using the second, more ambiguous question in the survey on public support.

Table 6 reports estimated average marginal effects for the main independent variables of interest, financing constraints and appropriability. [30] The main estimates of interest remain quite stable for SMEs: financing constraints are always negatively correlated to the use of tax incentives only, and they increase the likelihood of using direct support only. As for appropriability, firms that have used legal protection methods are more likely to use tax incentives, alone or in combination with subsidies. For the subsample of large firms some results change somewhat with respect to financing constraints. They become non significant for

[30] Remaining variables are included as in the baseline. Detailed results are available on request.

all four possible situations when we change the definition of dependent variables or of financing constraints. Appropriability does not seem to be correlated with support status, as in the baseline.

[Insert Table 6]

We now compare our results for using only direct support to those obtained by Gelabert et al. (2009), who used the same data base, keeping in mind that there are some differences with respect to the samples used as well as with respect to the empirical model. First, they use data for the years 2000 and 2002 to 2005, keep an unbalanced panel of firms that reported positive internal R&D expenditure at least one of these years in all sectors, including services, and average firm size is large. Second, they do not perform separate estimations for large firms and SMEs. Third, they estimate a univariate probit model, because they do not take into account the use of tax incentives. Otherwise, the definitions of appropriability and financing constraints are very close to ours. Our results partially differ from theirs: while they found that firms facing financial constraints are less likely to obtain public support, we find that the opposite effect for SMEs. With respect to appropriability, our results are basically in line with theirs.

6.3 Some further results: change of support status

While we do not have enough data to perform a dynamic analysis, we can complement our study by testing whether appropriability, financing constraints and previous R&D experience are related to the change in support status across the two periods, that is, the transition probabilities. Table 7 below reports the proportion of firms by support status in 2005 and their status in 2006-8. It shows that 40% of those SMEs that were not using any support in 2005 did obtain some during the next period (a similar percentage in the case of large firms). Most often they obtained a subsidy. There is a higher stability in support status among large firms than among SMEs, as 76% of large firms that used both types of support in

2005 kept having it during the following years. Among SMEs, however, 40% of those that had obtained a subsidy in 2005 did not use any support in the following period.

[Insert Table 7]

We are particularly interested in testing whether our core variables are related to the change of support status of firms that did not enjoy any in 2005. We can use a Multinomial logit model for that purpose, using as dependent variable support status in 2006-8, which has four possible values: 0 (no support), 1 (only subsidy), 2 (only tax incentives) and 3 (both). The probability of transition of a firm i from the state 0 (no support) to the state j`next period is given by:

$$Prob(S_{it}=j' \mid S_{it-1}=0) = (\exp(x_{it-1}\beta))/(\textstyle\sum_j \exp(x_{it-1}\beta)$$

where i=1,...N, and j'=0,1,2,3. We estimate these probabilities only for SMEs, as the number of large firms in each cell is too small, and with the two possible ways to compute financing constraints. We find that the probability of switching from no support to using only subsidies increases for firms with high human capital (8 pp); this is in fact the only significant variable. The probability of switching from no support to using only tax incentives increases if the firm has invested in R&D in 2005 (by 5pp), has used some form of intellectual property protection and its relative productivity is high. It falls if the firm has a small size. These results are in line with previous results. The role of financing constraints remains ambiguous, since for one of the measures it is negative and significant, but not significant for the second. Finally, the probability of switching to using both sources of support increases with human capital, productivity and firm size. New firms are also found more likely to switch to this status.

On the whole, our results suggest that although some firms use both tools, tax incentives and subsidies are used to a great extent by different types of firms. Tax incentives tend to be used by medium and large firms, firms that already invest in R&D, have high productivity and are able to protect their innovations, and firms from knowledge intensive industries. We find that financing constraints do not increase, but rather decrease, the likelihood of using this tool. Subsidies, instead, are more likely to be used by firms with high human capital that may or may not invested in R&D previously, and that are likely to be financially constrained. R&D subsidies would hence be better suited to address market failures associated to genuine innovation and to induce new entrants into R&D. We think that by jointly estimating the use of direct support and of tax credits, and by discriminating by firm size, we have been able to characterize better the use of both tools and their association to financing constraints and appropriability.

7. Conclusions

Our analysis has addressed the use by firms of two tools of public support to private R&D activities, direct support and tax incentives, assessing the link with potential barriers to innovation, with a special emphasis on the role of financial constraints, appropriability indicators and past R&D experience. To the best of our knowledge this is the first time that both policy instruments are compared from this perspective. Using data from a sample of two waves of the Spanish CIS survey, 2003-2005 and 2006-2008, we have estimated the determinants of the likelihood of using both tools at once, in isolation or none, separately for SMEs and large firms.

Our results do suggest that for SMEs there is an association between the source of market failures related to R&D and the use by firms of these two tools of public support to R&D, an issue that has not been previously studied in the literature. Financing constraints affect differently the likelihood that a firm will use each instrument. In particular, the probability of using tax incentives falls when firms face financing constraints, while the likelihood of using direct funding increases. There are differences as well regarding the effect of appropriability, as measured by the use of legal forms of protection. For large firms our findings are inconclusive. In both cases, however, tax incentives are more likely to be used by firms with past R&D experience, while subsidies may induce non-R&D doers to invest.

The main implication of these results is that tax incentives may not be a good instrument to address private R&D underinvestment when financing constraints, lack of appropriability and sunk costs are the main source of the problem, while direct support may be more appropriate. In that respect, our results are consistent with Berubé and Mohnen (2009), who found that among Canadian firms claiming tax credits those receiving subsidies are more likely to introduce products new to the world, and with Cappelen et al. (2012), who conclude that R&D tax credits in Norway result in the development of new production processes (possibly associated with low spillovers) rather than in new products for the market or in patents. Nevertheless, tax incentives may be useful in addressing small apropriability problems of firms that are not financially constrained, but more research is needed in this respect, distinguishing between large firms and SMEs.

On the whole, our evidence supports the hypothesis that tax incentives and direct funding are not substitutes from a policy perspective. The use of multiple policy instruments to address private underinvestment in R&D may be optimal in a second-best world with multiple market failures, informational and political and administrative capacity constraints. These issues have been considered in the design and implementation of environmental policies (Bennear and Stavins, 2007), and may be relevant for innovation policy as well. Solid evidence on the actual allocation and effects of each policy instrument should be further developed to guide instrument choice and design.

We think this paper contributes a step in that direction, even though we are aware of its limitations. In particular, one limitation of our work is that the available data does not allow us to take into account possible dynamic effects across and within instruments. Another limitation is that the Community Innovation Survey does not provide direct indicators of the threat of imitation as a barrier for innovation. Some project level information could be helpful in that regard, as well as adding some direct questions. Two further issues that are not addressed satisfactorily in the CIS survey are information on the degree of competition/ rivalry, and indicators of managerial practices and abilities.[31] As the design and administration of innovation surveys is spreading to the US and other non-European countries, reviewing the questions in light of the results of empirical work, might be not too costly and have a significant pay-off for enabling policy impact analysis.

[31] For an example of a survey on management practices that has been designed to quantify them and to test their association to productivity and other variables, see Bloom and Van Reenen (2007).

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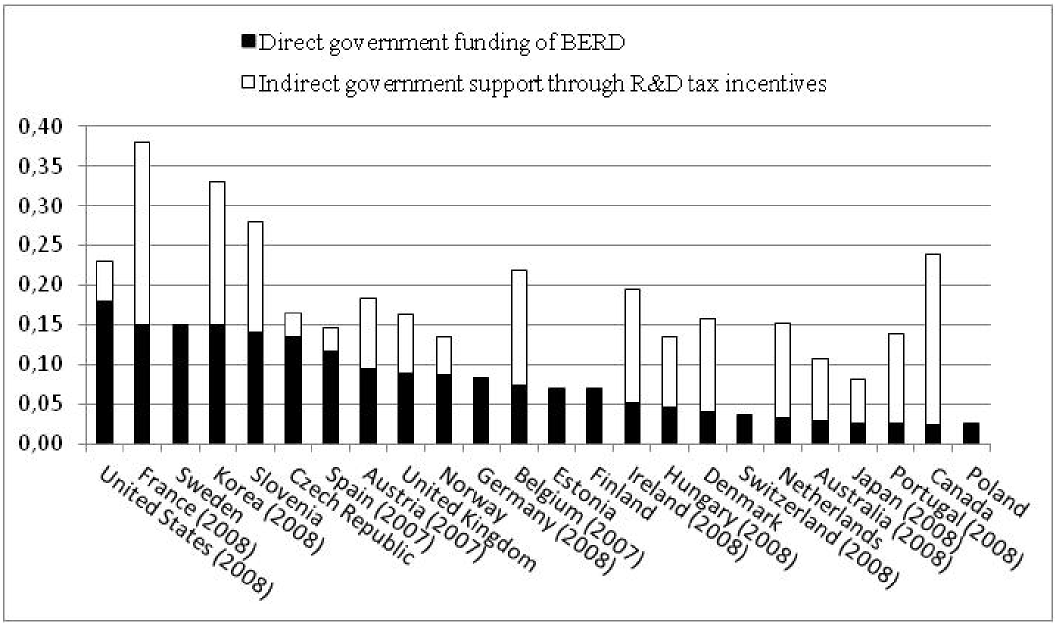
Figure 1. Direct funding and Tax Incentives for Business R&D 2009

(in % of GDP)



Notes: Direct funding includes grants, credits and public procurement. Indirect funding refers to forgone tax revenue from all tax incentives related to R&D: tax credits and allowances, social security contributions, reductions in R&D labour taxes. Sub-national tax incentives are not included. China, Greece, Iceland, Israel, Italy, the Russian Federation and the Slovak Republic provide R&D tax incentives as well as direct support but cost estimates are not available and are thus excluded from this graph; data on direct support in these countries is available in the source.

Source: Adapted from OCDE (2011a), OECD Science, Technology and Industry Scoreboard 2011

Table 1: Public Support to private R&D in 2006-2008

	SMEs		Large firms	
	N	%	N	%
Firms with no public support	1848	47	341	36
Firms with only subsides	923	23	162	17
Firms with only tax credits	679	17	241	26
Firm with both types of support	462	12	189	20
Total number of firms	3912	100	933	100

Notes: Subsidies here includes only grants. The total number of firms shown is the maximum number of observations in the sample. Sample size will be smaller in estimations because of missing values for some observations. We have discarded firms that do not intend to innovate because they declare that innovating is not necessary.

Table 2: Barriers in 2005 and Support Status in 2008

	SMEs				Large firms			
	No support	Use only Subsidies	Use only tax credits	Use both	No support	Use only Subsidies	Use only tax credits	Use both
Financing Constraints	41%	43%	32%	36%	24%	27%	23%	25%
Demand risk	21%	21%	19%	21%	12%	12%	15%	14%
Dominant firms	21%	19%	19%	24%	14%	21%	16%	14%
Lack of information	14%	14%	11%	14%	5%	9%	11%	9%
Lack of personnel	14%	14%	12%	12%	6%	8%	6%	8%
Protect innovations	31%	33%	45%	44%	29%	40%	41%	51%

Notes:
Financing barriers includes both internal and external sources; lack of information includes both market and technological information. N=3685 SMEs and N=835 Large firms (the number of firms in estimations may be slightly smaller due to missing data).

Table 3: Firm size, human capital and productivity by support status.

Median value

	SMEs				Large			
	No support	Use only Subsidies	Use only tax credits	Use both	No support	Use only Subsidies	Use only tax credits	Use both
Firm size Number of employees	34	32	46	48	319	375	380	341
% Employees with higher education	12%	12%	15%	18%	7%	9%	10%	12%
Relative Productivity	0.68	0.68	0.89	0.86	0.87	0.99	1.06	1.07
Did R&D in 2005 (%)	70%	73%	90%	91%	51%	65%	90%	89%

Notes: All variables except support status refer to 2005. Support refers to the years 2006-2008, while firm characteristics refer to 2005. Relative Productivity is computed as the firm's sales/employee over the industry mean

Table 4. SMEs. Bivariate Probit Regression
Average Marginal Effect (AME) on the probability of using...

	Only tax incentives	*Only subsidies*	*No public support*	*Both types of support*
Variable	AME	AME	AME	AME
Financially constrained	-.038***	.039***	.004	-.006
	(.012)	(.014)	(.017)	(.009)
Dominant firm	-.003	-.000	.007	-.004
	(.009)	(.011)	(.014)	(.007)
Demand risk	.008	.005	-.029**	.016**
	(.010)	(.012)	(.014)	(.007)
Appropriability	.029***	-.014	-.035**	.020***
	(.010)	(.012)	(.015)	(.008)
Log of Relative productivity	.029***	-.026***	-.038***	.023***
	(.004)	(.008)	(.010)	(0.005)
Low educated employees	-.057***	.024	.078***	-.044***
	(.021)	(.022)	(.028)	(.015)
High educated employees	.017	.042**	-.122***	.064***
	(.017)	(.020)	(.024)	(.012)
Capital investment	.039***	-.010	-.066***	.037***
	(.013)	(.015)	(.019)	(.010)
Take into account tax incentives	.123***	-.056***	-.159***	.092***
	(.009)	(.012)	(.014)	(.008)
Group membership	.018	-.017	-.004	.004
	(.013)	(.016)	(.019)	(.010)
Private domestic firm	.047**	-.027	-.495*	.029*
	(.020)	(.025)	(.029)	(.015)
Exporter	.042***	-.029**	-.035**	.022**
	(.012)	(.014)	(.017)	(.009)
Did in-house R&D	.093***	-.044***	-.117***	.067***
	(.013)	(.016)	(.019)	(.010)
Size 1	-.074***	.030	.102***	-.058***
	(.017)	(.021)	(.025)	(.013)
Size 2	-.033**	.006	.068***	-.037***
	(.015)	(.019)	(.023)	(.012)
Size 3	-.034**	.009	.056**	-.031***
	(.015)	(.019)	(.023)	(.012)
New firm	-.042	.051	-.009	.001
	(.034)	(.040)	(.048)	(.025)
Located in technological park	.067**	-.031	-.087*	.050**
	(.031)	(.038)	(.048)	(.025)
N observations	654	832	1691	446

Notes: ***, ** and * indicate significance at a 1%, 5% and 10% level, respectively; Total number of observations: 3623; Wald chi2(48)=691.69; Log Pseudolikelihood= -4131.3142; rho= 0.08 (s.e.=0.03). Regional and industry binary variables have been included. The omitted firm size category is 100-199 employees.

Table 5. Large Firms. Bivariate Probit Regression
Average Marginal Effect (AME) on the probability of using...

	Only tax incentives	*Only subsidies*	*No public support*	*Both types of support*
Variable	AME	AME	AME	AME
Financially	-.044	.020	.079*	-.056*
constrained	(.032)	(.027)	(.043)	(.033)
Dominant firm	-.027	.019	.018	-.010
	(.022)	(.019)	(.027)	(.021)
Demand risk	-.002	-.007	.040	-.031
	(.027)	(.023)	(.028)	(.022)
Appropriability	-.028	.032	-.036	.032
	(.026)	(.023)	(.028)	(.022)
Log of Relative	.012	.006	-.073***	.055***
productivity	(.019)	(.016)	(.022)	(.017)
Low educated	-.143***	.108***	.067	-.032
employees	(.047)	(.039)	(.055)	(.042)
High educated	.056	-.038	-.049	.030
employees	(.046)	(.040)	(.051)	(.040)
Capital investment	.037	-.033	.008	-.011
	(.043)	(.038)	(.052)	(.040)
Take into account	.146***	-.095***	-.137***	.086***
tax incentives	(.023)	(.021)	(.026)	(.021)
Group membership	.030	-.024	-.010	.005
	(.030)	(.026)	(.033)	(.026)
Private domestic	.019	.003	-.086***	.065***
firm	(.028)	(.024)	(.031)	(.024)
Exporter	.007	.010	-.070*	.054*
	(.035)	(.030)	(.040)	(.031)
Did in-house R&D	.131***	-.059**	-.244***	.171***
	(.029)	(.025)	(.034)	(.029)
Size 1	-.006	-.016	.095**	-.073**
	(.040)	(.034)	(.045)	(.034)
Size 2	.055	-.060	.056	-.051
	(.045)	(.039)	(.048)	(.037)
Size 3	.001	-.013	.055	-.043
	(.056)	(.049)	(.060)	(0.47)
New firm	-.148***	.152***	-.111	.107
	(0.43)	(.074)	(.303)	(.232)
Located in	-.117	.109	-.036	.045
technological park	(.085)	(.074)	(.085)	(.066)
N observations	203	143	300	160

Notes: ***, ** and * indicate significance at a 1%, 5% and 10% level, respectively; standard errors in parentheses. Total number of observations=806; Wald chi2(48)=254.12; Log Pseudolikelihood=-942.91536; rho=0.12 (s.e.=0.06). Regional and industry binary variables have been included.

Table 6. Robustness Analysis

Average Marginal Effects of financing constraints and appropriability by support status[a]

Panel A: SMEs	*Financially constrained*				*Appropriability*			
Type of support:	*None*	*TC*	*S*	*TC+S*	*None*	*TC*	*S*	*TC+S*
Baseline		-.04	.04		-.04	.03		.02
Dep var as in Baseline, Subsample of firms that introduced products new to the market in 2003-2005		-.04	.04					
Dep. var. as in Baseline, Subsample of firms that did R&D in 2005		-.04	.04			.03		
Dep. var. as in Baseline Subsample of firms in high and medium-high tech industries		-.04			-.06			.03
Dep. var. as in Baseline Change in computation of financing constraints	.04	-.05	.03	-.02	-.03	.03		.02
Change in Dependent Variables: Subsidy and TI in 2008, whole sample		-.04	.02		-.06	.03	.01	.02
Change in Dependent Variables: Subsidies+Loans and TI 2006-8[b]		-.05	.02		-.05	.02		.02

Panel B: Large Firms	*Financially constrained*				*Appropriability*			
	None	*TC*	*S*	*TC+S*	*None*	*TC*	*S*	*TC+S*
Baseline	.08			-.06				
Dep. Var. as in Baseline Subsample of firms that did R&D in 2005	-.11			-.10				
Dep. Var. as in Baseline Change in computation of financing constraints								
Dep. Var. as in Baseline Subsample of firms in high and med-high tech industries	.10							.07
Change in dependent variables: Subsidy and TI in 2008, whole sample								
Change in Dependent Variables: *Subsidies and Loans, and TI 2006-8*		-.08	.06		-.05	-.05	.04	.05

Notes: (a) Only significant estimates are reported; blank cells indicate a non-significant estimate has been obtained. For large firms estimations for some subsamples could not be performed because the number of observations in some of the categories was too small (less than 45 firms).

(b) The estimated correlation between errors of both equations is higher for both samples (rho=0.30 (se =0.03) for SMEs, and rho=0.36 (s.e.=0.06) for large firms). This possibly reflects the fact that the question is phrased in such a way that there is some ambiguity as to whether to include tax incentives as public support.

Table 7: Changes of support status

Support Status 2005	Support Status 2008, SMEs						Support Status 2008, Large firms					
	None	S	TC	S+TC	Total	N firms	None	S	TC	S+TC	Total	N firms
None	60.2	28.3	6.9	4.6	100	2631	62.3	25.3	8.1	4.2	100	454
S	39.7	38.0	8,2	14.1	100	184	21.6	54.9	9.8	13.7	100	51
TC	4.5	1.9	59.5	34.1	100	694	2.5	0.0	61.0	36.6	100	240
S+TC	1.7	3.5	38.6	56.1	100	114	0.0	0.0	24.6	75.4	100	61

Note: None=No Subsidy, No Tax Credit; S = Subsidy, No Tax Credit; TC= No Subsidy, Tax Credit; S+TC= Subsidy and Tax Credit.

APPENDIX A

Main features of R&D tax incentives and direct support in Spain.

Tax Incentives

R&D Tax incentives for R&D investment have been in place in Spain since 1995, when a new law on corporate taxation was introduced. The definition of R&D eligible expenses follows the OECD Frascati Manual guidelines. In 1999 (Act 55/99) some non-RD technological innovation expenditures were included as eligible for tax credit at a 10% or 15% rate, depending on the type of expenditure. Tax credit rates were initially 20% of R&D volume, and 40% of the excess on average R&D expenditures of the two preceding years, with a cap of 35% of the tax liability. In 2001 (Act 24(01)r both rates were increased (to 30% and 50% respectively), as well as the cap (to 50% for SMEs if the credit was greater than 10% of the tax liability., In 2004, in addition, 20% of the labour cost of employees assigned exclusively to R&D tasks could be deducted. Rates were somewhat reduced in 2007 and 2008. From 2007 onwards, firms could use the alternative option of deducting from the social security tax 40% of the liability corresponding to R&D employees. Excess credit can be carried forward up to 15 years. Firms that obtain R&D and innovation subsidies can claim tax credits on all R&D expenditure remaining after substracting 65% of the subsidies received. For further information see http://www.minhap.gob.es/es-ES/Areas%20Tematicas/Impuestos/Direccion%20General%20de%20Tributos/Paginas/Direccion%20general%20de%20tributos.aspx

Direct support to R&D and innovation through CDTI.

The annual reports of the main funding agency, CDTI, provide the following information about direct support during the period studied in this paper. In 2006, CDTI contributed 802 Million € to 1032 projects (out of 1434 applications). Most of the funding (50%) was allocated to technological development projects; 14% to technological innovation projects (mostly adoption of innovations); 9% to cooperative industrial research, 25% to large public-private research consortia (CENIT projects, launched in 2005; first call in 2006). The first three types were offered 0-interest loans and up to a 20% grant, depending on the features of the project. CENIT projects were offered grants of up to 50% of the R&D budget; these are 4 year-long projects, with budgets between 20 to 40 Million€. Loans were offered to new technology based firms of up to 70% of the budget of the project, with maximum funding of 400 thousand € (Neotec Projects). In 2007, CDTI contributed 1090 Million € to 1111 projects. The budget across project types changes somewhat over time. In 2008, projects i) and ii) were combined in a single category so as to comply with EU state aid rules. Total CDTI funding decreased to 766 Million€ that were allocated to 1124 projects. 67% of funding was allocated to projects in the new merged category. The grant rate was increased to 25%. CDTI provides advice on tax incentives to firms that obtain direct support. It issues at no cost for the firm a certificate of the project as being either an “R&D project” or a “Technological Innovation project”. This certificate enables the firm to directly claim tax credits and is binding for the tax authority.

APPENDIX B: Sample Descriptive Statistics by Support and Size

SMEs	No support N=1691		Only subsidies N=832		Only tax credits N=654		Subsidies and tax credits N=446	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Awareness of constraints	.50	.23	.51	.23	.50	.20	.51	.21
Financially constrained	.40	.49	.43	.50	.31	.46	.35	.48
Lack of personnel	.14	.35	.14	.35	.12	.32	.12	.32
Lack of information	.14	.35	14	.34	.12	.32	.13	.34
Dominant firm	.21	.41	.20	.40	.20	.40	.24	.43
Demand risk	.21	.41	.20	.40	.19	.39	.22	.41
Appropriability	.31	.46	.33	.47	.44	.50	.46	.50
Log of Relative productivity*	-.43	.75	-.48	.98	-.15	.63	-.19	.66
Fixed Investment	.76	.43	.78	.41	.88	.33	.89	.32
Low educated employees*	.15	.35	.13	.33	.03	.18	.03	.17
High educated employees*	.07	.25	.11	.32	.12	.32	.18	.38
Take into account tax incentives	.31	.46	.33	.47	.62	.49	.64	.48
Group membership*	.20	.40	.19	.39	.30	.46	.32	.47
Private domestic firm*	.93	.25	.93	.25	.92	.27	.92	.27
Exporter*	.67	.47	.65	.48	.82	.38	.83	.38
Did in-house R&D*	.70	.46	.73	.44	.90	.30	.91	.28
Log of number of employees*	3.51	.93	3.47	.97	3.82	.89	3.85	.91
New firm*	.02	.14	.03	.18	.02	.12	.02	.15
Age*	22.3	17.4	21.7	17.7	24.5	17.8	24.8	18.6
Located in technological park	.01	.12	.02	.14	.04	.18	.05	.22
Region: Madrid	.08	.27	.08	.28	.06	.24	.07	.25
Region: Catalonia	.27	.44	.26	.44	.38	.48	.34	.48
Region: Andalusia	.06	.24	.05	.22	.03	.18	.03	.17
Firm in high tech sector	.07	.26	.11	.31	.13	.34	.17	.38
Firm in med-high sector	.32	.47	.29	.45	41	.49	.40	.49
Firm in med-low sector	.28	.45	.28	.45	.22	.41	.22	.41

Notes: All variables are binary except for Log of Relative Productivity, Share of highly educated employees, los of number of employees and age. Variables marked * refer to year 2005; otherwise they refer to the period 2003-2005. The share of highly educated employees refers to 2006, the first year this variable becomes available. The number of observations in each category corresponds to the number of observations effectively available in the sample used in the estimation of the baseline. It differs from previous tables because for some observations some variables have missing values.

LARGE Firms	No support N=300		Only subsidies N=143		Only tax credits N=203		Subsidies and tax credits N=160	
	Mean	Sd	Mean	sd	Mean	Sd	Mean	sd
Awareness of constraints	.39	.25	.45	.25	.45	.21	.45	.21
Financially constrained	.25	.43	.28	.45	.24	.43	.26	.44
Lack of personnel	.07	.25	.10	.30	.05	.23	.07	.26
Lack of information	.06	.24	.12	.32	.10	.30	.11	.31
Dominant firm	.15	.36	.22	.41	.15	.36	.14	.35
Demand risk	.12	.32	.15	.36	.14	.35	.13	.34
Appropriability_a	.27	.45	.42	.50	.44	.50	.49	.50
Log of Relative productivity*	-.23	.75	-.10	.60	.02	.59	.01	.65
Fixed Investment	.90	.30	.91	.29	.95	.23	.93	.25
Low educated employees*	.18	.38	.16	.37	.02	.14	.03	.17
High educated employees	.05	.22	.06	.23	.11	.31	.12	.32
Take into account tax incentives	.42	.49	.39	.49	.71	.45	.71	.45
Group membership*	.73	.44	.70	.46	.78	.42	.78	.41
Private domestic firm*	.66	.48	.65	.48	.64	.48	.76	.43
Exporter*	.80	.40	.85	.36	.87	.33	.91	.29
Did in-house R&D*	.50	.50	.65	.48	.90	.30	.89	.31
Log of number of employees*	5.97	.65	6.06	.65	6.09	.65	6.12	.78
New firm*	.003	.06	0	0	0	0	.01	.11
Age*	31.8	23.1	34.1	21.7	35.2	22.9	35.9	22.9
Located in technological park	.01	.11	.03	.18	.01	.12	.03	17.4
Region: Madrid	.17	.38	.15	.36	.18	.38	.13	.34
Region: Catalonia	.29	.46	.27	.44	.37	.48	.31	.46
Region: Andalusia	.04	.20	.04	.20	.01	.12	.03	.16
Firm in high tech sector	.06	.23	.11	.32	.13	.34	.14	.35
Firm in med-high sector	.27	.44	.29	.45	.34	.47	.36	.48
Firm in med-low sector	.27	.45	.30	.46	.25	.43	.27	.44

Notes: All variables are binary except for Log of Relative Productivity, Share of highly educated employees, los of number of employees and age. Variables marked * refer to year 2005; otherwise they refer to the period 2003-2005. The share of highly educated employees refers to 2006, the first year this variable becomes available. The number of observations in each category corresponds to the number of observations effectively available in the sample used in the estimation of the baseline. It differs from previous tables because for some observations some variables have missing values.

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